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(54) ELECTROMAGNETIC DRIVE TYPE ANGULAR VELOCITY SENSOR AND ITS MANUFACTURE

(57)Abstract:
PROBLEM TO BE SOLVED: To provide an electromagnetic drive type angular velocity sensor capable of detecting angular velocity with high accuracy by a simple structure.
SOLUTION: A glass substrate 11, a vibrator 20 disposed on an upper surface of the glass substrate 11, and a permanent magnet 12 mounted on an under surface of the glass substrate 11, form a three-layer structure. The vibrator 20 is equipped with a substantially square vibrator weight 21 formed to have four sides each supported in midair by two support beams 22 and metallic wires 21a formed on a surface of the vibrator weight 21 so as to connect two support beams neighboring each other on each side. Each support beam is formed into an L-shape so as to have a part extending vertically from each side of the vibrator and a part being bent at a right angle at an end thereof and extending therefrom.

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CLAIMS

[Claim(s)]
[Claim 1] The vibrator which has the weight which has the symmetry in which electrode wiring was formed, and two or more supporting beams which support this weight elastically in a symmetrical location, It has the magnet which acts a uniform field on the above-mentioned weight, and the above-mentioned vibrator in a top-face side. It is the supporting beam for an actuation oscillation in which the electric wiring and electrode wiring of the above-mentioned weight which were equipped with the substrate which has the above-mentioned magnet in an underside side, and up Norikazu's supporting beam formed in this top face were formed to one electrical circuit. It is a supporting beam for the detection oscillation whose the supporting beam besides the above formed in one electrical circuit the electric wiring and electrode wiring of the above-mentioned weight which were formed in this top face. By passing a current to the supporting beam for the above-mentioned actuation oscillation, a Lorentz force acts on the weight of the above-mentioned vibrator, and it vibrates. the electromagnetism which

Coriolis force acts by impression of angular velocity, detects the induced electromotive force which the weight of the above-mentioned vibrator vibrates in the oscillating direction and the direction of a right angle by the above-mentioned Lorentz force, and is generated at the ends of the supporting beam for the above-mentioned detection oscillation, and detects angular velocity -- an actuation mold angular-velocity sensor.

[Claim 2] the electromagnetism according to claim 1 which said weight is an abbreviation square configuration and is characterized by making the same width of face of the supporting beam for said actuation oscillation, and width of face of the supporting beam for said detection oscillation, and making it have high sensitivity with a resonance mold -- an actuation mold angular-velocity sensor.

[Claim 3] the electromagnetism according to claim 1 which changes the width of face of the supporting beam for said actuation oscillation to the width of face of the supporting beam for said detection oscillation, and is characterized by adjusting the oscillation frequency of an actuation oscillation and a detection oscillation -- an actuation mold angular-velocity sensor.

[Claim 4] electromagnetism given in claim 1 thru/or any of 3 they are -- an actuation mold angular-velocity sensor. [which is characterized by having arranged the supporting beam for said detection oscillation of a couple in the symmetric position, and arranging the supporting beam for said actuation oscillation of a couple in a symmetric position to the detection oscillating direction by said Coriolis force to the actuation oscillating direction by said Lorentz force]

[Claim 5] electromagnetism given in claim 1 thru/or any of 4 they are -- an actuation mold angular-velocity sensor. [which is characterized by using it in atmospheric pressure]

[Claim 6] The process which forms the thermal oxidation film in the front flesh side of a silicon substrate, and carries out patterning to a rear face, The process which etches the rear face of a silicon substrate by using the above-mentioned thermal oxidation film as a mask, and forms a gap, The process which removes the thermal oxidation film of the rear face of the above-mentioned silicon substrate, forms an electrode by sputtering on the surface of a silicon substrate, and forms metal wiring and the polar zone by patterning, The process which forms a resist pattern on the surface of a silicon substrate, and removes the thermal oxidation film of the above-mentioned silicon substrate surface by etching in the part corresponding to the weight and supporting beam of the above-mentioned metal wiring, the above-mentioned polar zone, and a trembler, The process in which a silicon substrate carries out penetration etching by reactive ion etching by using the above-mentioned resist pattern as a mask, electromagnetism equipped with the process which removes the above-mentioned resist pattern and carries out anode plate junction of the above-mentioned silicon substrate and the glass substrate, and the process which connects lead wire to the above-mentioned polar zone, and attaches a permanent magnet in the underside of the above-mentioned glass substrate --

the manufacture approach of an actuation mold angular-velocity sensor.
[Claim 7] the electromagnetism according to claim 6 to which penetration etching for forming said supporting beam is characterized by being inductively-coupled-plasma reactive ion etching -- the manufacture approach of an actuation mold angular-velocity sensor.

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Field of the Invention] an angular-velocity sensor for this invention to detect an objective angular velocity, especially electromagnetism -- it is related with an actuation mold angular-velocity sensor and its manufacture approach.
[0002]
[Description of the Prior Art] Conventionally, as an angular-velocity sensor, the angular-velocity sensor of a configuration as shown, for example in drawing 12 and drawing 13 is known. first, the angular-velocity sensor 1 shown in drawing 12 -- electromagnetism -- it is the angular-velocity sensor of actuation and a piezo-resistance detection mold, and as shown in drawing 12 (A), it consists of the glass substrate 3 laid one by one on the base 2, a silicon substrate 4, a glass substrate 5, and a permanent magnet 6. Here, as the above-mentioned silicon substrate 4 is shown in drawing 12 (B), it has two vibrator 4a and 4b formed so that it might rank with parallel mutually in the level surface, and, as for these vibrator 4a and 4b, ends are connected to 4d of outer frame parts through two thin rod-like connection section 4c, respectively. Furthermore, inside connection section 4c is equipped with piezoresistance 4e for detection formed in the front face among such connection section 4c. In addition, in drawing 12 (B), the z-axis is the direction of a detection oscillation, and a x axis is the direction of an actuation oscillation.
[0003] According to the angular-velocity sensor 1 of such a configuration, to Vibrator 4a and 4b, as an arrow head I shows by drawing 12 (B) an actuation current passes -- having -- Vibrator 4a and 4b -- electromagnetism -- when Vibrator 4a and 4b vibrates in response to angular velocity in the condition of driving, the resistance of piezoresistance 4e formed in the front face of this connection section 4c changes with the stress which joins the above-mentioned connection section 4c by the longitudinal oscillation of these z shaft orientations. The angular velocity which joins Vibrator 4a and 4b is detected by measuring and processing this resistance value change as for example, a current value change.
[0004] Moreover, the angular-velocity sensors 7 shown in drawing 13 are electrostatic

actuation and a capacity detection mold angular-velocity sensor, consist of glass substrates 7a and 7b arranged so that it might be parallel mutually [a couple], and vibrator 8 arranged among these glass substrates 7a and 7b, and have three layer systems. Torsion-bar-spring 8b of the beam for angular-velocity detection with which this angular-velocity sensor 7 was horizontally prolonged inside like a graphic display, and ends were supported by outer frame partial 8a, Vibrator 8 consists of weights 8d and 8e supported by two ends of cantilever 8c of the beam for actuation which crosses mutually and is aslant prolonged from the center of this torsion-bar-spring 8b, and the electrode is formed in the vertical side of the weight of these vibrator. Here, 8d of weights of a trembler is located in the 1 side of the above-mentioned torsion-bar-spring 8b, and they are arranged so that weight 8e of a trembler may be located in the side else. On the other hand, the above-mentioned glass substrates 7a and 7b equip the inner surface which counters mutually with the electrodes 7c and 7d for electrostatic actuation and the electrodes 9a and 9b for electrostatic actuation monitors which counter 8d of weights of the above-mentioned vibrator, and the electrodes 7e and 7f for capacity detection which counter weight 8e of the above-mentioned vibrator.

[0005] According to the angular-velocity sensor 7 of such a configuration, the driver voltage supplied from the power source which is not illustrated is impressed to the electrode for electrostatic actuation, and carries out the actuation oscillation of the 8d of the weights of vibrator according to electrostatic force. At this time, weight 8e of the vibrator supported by the opposite hand of cantilever 8c will vibrate similarly. When vibrator vibrates in response to angular velocity in this condition, the distance between weight 8e of vibrator and the electrodes 7e and 7f for capacity detection is changed, and the capacity between these changes. The angular velocity of vibrator is detected by measuring and processing this capacity change suitably.

[0006]

[Problem(s) to be Solved by the Invention] However, the respectively following technical problems which should be solved occur in the angular-velocity sensors 1 and 7 constituted in this way. That is, in the angular-velocity sensor 1, while piezoresistance 4e was formed in the front face of connection section 4c which supports two vibrator 4a and 4b, it might be said that it was four layer systems of a glass substrate 3, a silicon substrate 4, a glass substrate 5, and a permanent magnet 6, structure will become complicated, and a manufacturing cost will become high. Moreover, since the oscillation modes of an actuation oscillation of Vibrator 4a and 4b and the detection oscillation based on the angular velocity which should be detected differ, the tuning of the resonance frequency of these oscillations will be needed, and cost will become high.

[0007] On the other hand, although an external component is unnecessary in the angular-velocity sensor 7 shown in drawing 13 since electrostatic actuation of the 8d of the weights of vibrator is carried out If big driver voltage is impressed, since it will collide with the actuation electrode with which the weights 8d and 8e of a trembler

counter by the effect of the structural imbalance of 8d of weights of a trembler becoming large In order to avoid such a collision, the actuation amplitude is small, therefore the technical problem which should be solved that the detection precision of angular velocity was low occurred. Moreover, since the resonance frequency of an actuation oscillation of Vibrator 4a and 4b and the detection oscillation based on the angular velocity which should be detected differed like the angular-velocity sensor 1, the tuning which doubles such resonance frequency was needed, and the case of this angular-velocity sensor 7 also had the technical problem that cost will become high. Furthermore, since the angular-velocity sensor 7 whole carried out capacity detection of the oscillation of weight 8e of vibrator and it needed to narrow the gap between weight 8e of vibrator, and the electrodes 7e and 7f for capacity detection, in order to eliminate the effect of air damping, the vacuum lock of the vibrator needed to be carried out, and the technical problem that cost will become high occurred.

[0008] the electromagnetism by which angular velocity may have been detected with high degree of accuracy by the easy configuration in view of the point of a more than [this invention] -- it aims at offering an actuation mold angular-velocity sensor and its manufacture approach.

[0009]

[Means for Solving the Problem] in order to attain the above-mentioned object -- the electromagnetism of this invention -- invention according to claim 1 among actuation mold angular-velocity sensors The vibrator which has the weight which has the symmetry in which electrode wiring was formed, and two or more supporting beams which support weight elastically in a symmetrical location, It has the magnet which acts a uniform field on weight, and the substrate which has vibrator in a top-face side and has a magnet in an underside side. It is the supporting beam for an actuation oscillation in which the electric wiring and electrode wiring of weight which the supporting beam of 1 formed in the top face were formed to one electrical circuit. It is the supporting beam for a detection oscillation in which the electric wiring and electrode wiring of weight which other supporting beams formed in the top face were formed to one electrical circuit. By passing a current to the supporting beam for an actuation oscillation, a Lorentz force acts on the weight of vibrator and it vibrates. Coriolis force acted by impression of angular velocity, and it considered as the configuration in which the weight of vibrator detects the induced electromotive force vibrated and generated in the oscillating direction and the direction of a right angle by the Lorentz force at the ends of the supporting beam for a detection oscillation, and angular velocity is detected. Furthermore, in addition to the above-mentioned configuration, invention according to claim 2 is characterized by the weight of a trembler being an abbreviation square configuration, making the same width of face of the supporting beam for an actuation oscillation, and width of face of the supporting beam for a detection oscillation, and making it have high sensitivity with a resonance mold. Moreover, invention according

to claim 3 is characterized by having changed the width of face of the supporting beam for an actuation oscillation to the width of face of the supporting beam for a detection oscillation, and adjusting the oscillation frequency of an actuation oscillation and a detection oscillation. Furthermore, invention according to claim 4 is characterized by having arranged the supporting beam for the detection oscillation of a couple in the symmetric position, and arranging the supporting beam for the actuation oscillation of a couple in a symmetric position to the detection oscillating direction by Coriolis force to the actuation oscillating direction by the Lorentz force. moreover, invention according to claim 5 -- electromagnetism -- it is characterized by using an actuation mold angular-velocity sensor in atmospheric pressure.

[0010] According to such a configuration, if a current is passed to the supporting beam for an actuation oscillation, a Lorentz force will act on the weight of vibrator based on a field with the current and magnet which flow to the weight of vibrator. Consequently, vibrator vibrates to a magnetic field and a right-angled horizontal direction. If angular velocity is impressed by vertical shaft orientations from this condition, vibrator will vibrate by Coriolis force to the angular-velocity direction, and a driving direction and a right-angled horizontal direction. Therefore, angular velocity is detectable by induced electromotive force's occurring in the supporting beam for a detection oscillation, measuring the electrical potential difference by this induced electromotive force, and performing proper processing by this oscillation, based on this electrical potential difference. moreover -- if width of face of the supporting beam for an actuation oscillation and width of face for a detection oscillation are made the same -- electromagnetism -- since the oscillation (detection oscillation) generated with the oscillating direction and angular velocity by actuation is the same oscillation mode, the resonance frequency becomes equal and it serves as a perfect resonance mold. Oscillation frequency changes by changing the width of face of further one of the two's supporting beam. Therefore, since the oscillation frequency of an actuation oscillation and a detection oscillation is in agreement, sensibility can become high, moreover oscillation frequency can be adjusted freely, and the frequency characteristics of an angular-velocity sensor can be raised. furthermore, vibrator -- electromagnetism -- since an actuation oscillation is given by actuation, while the actuation amplitude becomes large and angular velocity will be detected with high degree of accuracy, since it is hard to be influenced of air damping, the vacuum lock of vibrator becomes unnecessary, and cost decreases.

[0011] moreover, the electromagnetism of this invention -- the manufacture approach of an actuation mold angular-velocity sensor The process which forms the thermal oxidation film in the front flesh side of a silicon substrate, and carries out patterning to a rear face, The process which etches the rear face of a silicon substrate by using the thermal oxidation film as a mask, and forms a gap, The process which removes the thermal oxidation film of the rear face of a silicon substrate, forms an electrode by

sputtering on the surface of a silicon substrate, and forms metal wiring and the polar zone by patterning, The process which forms a resist pattern on the surface of a silicon substrate, and removes the thermal oxidation film of a silicon substrate surface by etching in the part corresponding to the weight and supporting beam of metal wiring, the polar zone, and a trembler, The process in which a silicon substrate carries out penetration etching by reactive ion etching by using a resist pattern as a mask, The resist pattern was removed and it considered as the configuration equipped with the process which carries out anode plate junction of a silicon substrate and the glass substrate, and the process which connects lead wire to the polar zone and attaches a permanent magnet in the underside of a glass substrate. Moreover, it is preferably characterized by penetration etching being inductively-coupled-plasma reactive ion etching.

[0012] such a configuration -- the electromagnetism of this invention -- by the manufacture approach of an actuation mold angular-velocity sensor, a mask required for a fabrication of an angular-velocity sensor can be managed with three sheets, and a fabrication process becomes very easy. Moreover, since penetration etching of a silicon substrate is etching with a very sufficient anisotropy, vibrator can be formed in accuracy with structurally sufficient symmetric property, and the weight of vibrator can be greatly formed as compared with the magnitude of the whole angular-velocity sensor.

[0013]

[Embodiment of the Invention] the electromagnetism of this invention -- an actuation mold angular-velocity sensor is equipped with the supporting beam to which the vibrator arranged for example, on the glass substrate supports elastically the tabular weight which has the center of symmetry in which electrode wiring was formed, and this weight in a symmetrical location, and has the magnet which makes a uniform field act on the current which flows to electrode wiring formed in weight. A permanent magnet is sufficient as this magnet. The configuration which the weight of vibrator has center of symmetry and becomes big weight may be good, for example, the shape of the shape of a rectangle or an abbreviation square has as it.

[0014] moreover, this electromagnetism -- the actuation mold angular-velocity sensor is equipped with the supporting beam for the actuation oscillation of a couple, and the supporting beam for a detection oscillation of the couple which detects the oscillation by Coriolis force when angular velocity is impressed as a supporting beam which supports the weight of a trembler. As opposed to the detection oscillating direction, the supporting beam for a detection oscillation is arranged in the symmetric position for the supporting beam for an actuation oscillation to the actuation oscillating direction, respectively. Wiring formed on the supporting beam further for each actuation oscillation and each electrode wiring formed in the symmetric position at weight are connected to one electrical circuit, and one electrical circuit is formed with each electrode wiring with which wiring formed on the supporting beam for each detection oscillation was similarly formed in the symmetric position of weight.

[0015] the electromagnetism of such a configuration -- by the actuation mold angular-velocity sensor, if an alternating current is passed to electrode wiring of weight, a Lorentz force will act in the direction of a current, and the right-angled direction of the level surface (the same flat surface as vibrator) by the field, and vibrator will vibrate. If angular velocity is impressed by the vertical upper part of vibrator at this time, vibrator will vibrate by Coriolis force on the same flat surface of the actuation oscillating direction and the direction of a right angle. Induced electromotive force occurs to the ends of the supporting beam for the detection oscillation of a couple by this oscillation. Therefore, the angular velocity impressed from this induced voltage is known. Moreover, since an actuation oscillation and a detection oscillation are on the same field, it is made to a perfect resonance mold, and sensibility is high.

[0016] In addition, in order to improve symmetry, as for each supporting beam, considering as a couple is desirable, but even if it is not a couple, the structure which arranges each supporting beam in the 1 side of the actuation oscillating direction and the detection oscillating direction by Coriolis force is sufficient. Moreover, if the width of face of the supporting beam for the actuation oscillation by the side of one and the width of face of the supporting beam for the detection oscillation by the side of one are changed, the oscillation frequency of an actuation oscillation and a detection oscillation will change. Therefore, by changing the width of face of a supporting beam, the frequency characteristics of an angular-velocity sensor can be raised and it is made to a dissonance mold.

[0017] Hereafter, this invention is explained to a detail based on the operation gestalt shown in the drawing. In addition, the same sign was substantially used for the same or a corresponding thing. the electromagnetism according [drawing 1] to this invention -- 1 operation gestalt of an actuation mold angular-velocity sensor is shown. In drawing 1 , the angular-velocity sensor 10 consists of a glass substrate 11, vibrator 20 arranged in the front face of this glass substrate 11, and a permanent magnet 12 attached in the rear face of this glass substrate 11, and has three layer systems. the electromagnetism according [drawing 2] to this invention -- it is surface drawing showing other operation gestalten of an actuation mold angular-velocity sensor. Drawing 3 (a) is the B-B end-of-line side Fig. of drawing 2 , and drawing 3 (b) is the C-C end-of-line side Fig. of drawing 2 .

[0018] If drawing 1 thru/or drawing 3 are referred to, the field shown by L2 is vibrator 20, a gap is formed in the bottom of this vibrator 20, and the glass substrate 11 and the permanent magnet 12 are formed. in addition, the electromagnetism of drawing 2 -- the range of the actuation mold angular-velocity sensor 10L1 is one unit of an angular-velocity sensor. A glass substrate 11 is selected by for example, 300-micrometer thickness, and the permanent magnet 12 consists of for example, Sm-Co magnets. Furthermore, as for the silicon substrate 30, 200 micrometers in thickness and the die length L1 of each side are selected by about 10mm. each which

supports the weight 21 of the vibrator formed by the thickness of about 150 micrometers so that it might have the gap of about 50 micrometers, and the weight 21 of this vibrator to an underside side in drawing 2 in each side -- vibrator 20 consists of supporting beams 22 of a couple (namely, the whole 8). The weight 21 of the above-mentioned vibrator is supported by the supporting beams 22 and 22 of a couple in midair in the location it is about 7mm in [L2 / whose] a graphic display (for example, the die length of each side) and which entered inside in the mid-position of each side while having the square appearance mostly. furthermore, each which was formed in the front face so that the above-mentioned trembler 20 might connect the supporting point by the supporting beams 22 and 22 of the couple of each side -- it has the metal wiring 33a and 33b of a couple.

[0019] While being formed in L typeface so that it may have the part which is crooked from the part prolonged [as opposed to / respectively / each / from an inside supporting point / side] vertically, concerning each [of the weight 21 of vibrator] side as the above-mentioned supporting beam 22 is shown in drawing 1 and drawing 2 , and its head to a right angle, and is prolonged, it is selected by about 150 micrometers like [the thickness] the weight 21 of vibrator. And the head has extended even near [four] the corner of the weight 21 of vibrator, and fixed maintenance of each supporting beam 22 is carried out by carrying out anode plate junction to a glass substrate 21 there. By this, the weight 21 of a trembler will be held by each supporting beam 22 in midair on a glass substrate 11. Furthermore, as for each above-mentioned supporting beam 22, the polar zone (after-mentioned) is formed in the front face at the head.

[0020] Here, as the above-mentioned angular-velocity sensor 10 is shown in drawing 4 , it is manufactured. Drawing 4 is the mimetic diagram of the production process of the A-A end-of-line side of drawing 2 . In drawing 4 (A), patterning is first carried out to a rear face after forming the thermal oxidation film 31 in a front face and a rear face by oxidizing thermally the with a predetermined thickness, for example, 200-micrometer thickness, silicon substrate 30. This oxide film serves as the 1st mask. Next, in drawing 4 (B), by etching which used TMAH for the above-mentioned thermal oxidation film 31 from the rear face as the 1st mask, the gap 32 of 50 micrometers is formed and the thermal oxidation film 31 on the back is removed. Thereby, the thickness of the silicon substrate 30 corresponding to a gap 32 is set to 150 micrometers. Then, as shown in drawing 4 (C), by carrying out sputtering of Au/Cr, a metal membrane is formed in the front face of a silicon substrate 30, and the metal wiring 33 and polar-zone 33a are formed in it by patterning. Patterning of this metal membrane serves as the 2nd mask.

[0021] Then, as shown in drawing 4 (D), after forming a resist pattern 34 in the front face of a silicon substrate 30 in the part corresponding to the metal wiring 33, polar-zone 33a and the weight 21 of a trembler, and a supporting beam 22, the thermal oxidation film 31 is removed for this resist pattern 34 as the 3rd mask. Then, as shown in drawing 4 (E), a silicon substrate 30 is carried out for the above-mentioned resist

pattern 34 penetration etching 35 by ICPRIE (inductively-coupled-plasma reactive ion etching) as the 3rd mask, and a resist pattern 34 is removed after that. It is important to make an etch rate into homogeneity by this penetration etching, and to stop over etching. As shown in drawing 4 (F), while connecting lead wire 36 to polar-zone 33a and carrying out anode plate junction of a silicon substrate 30 and the glass substrate 11 finally, a permanent magnet 12 is attached by adhesion etc. to the underside of this glass substrate 11. In this way, the angular-velocity sensor 10 will be completed.

[0022] By such manufacture approach, formation of vibrator with big weight is made to accuracy, a mask required to form the gap of vibrator and a glass substrate further becomes three sheets, and a fabrication process becomes very easy.

[0023] Next, the function of the angular-velocity sensor 10 of this invention is explained. the electromagnetism which showed drawing 5 to drawing 1 -- it is the schematic diagram showing the measuring circuit for measuring the oscillation characteristic of an actuation mold angular-velocity sensor. In addition, 40 shows a network analyzer and 41 shows an operational amplifier. If drawing 5 is referred to, it will be attached in a body for the angular-velocity sensor 10 whole of this invention to measure angular velocity etc., and alternating voltage (for example, 0.3 ****-p) will be impressed from a network analyzer 40 to between the polar zone (electrode for actuation) 25 of the supporting beam of the couple corresponding to the one side of a trembler 20, and 26. thereby -- vibrator 20 -- the field of a permanent magnet 12 -- acting -- electromagnetism -- it drives and an actuation oscillation is started. And the induced electromotive force generated by this oscillation is amplified with ejection and an operational amplifier 41 from the polar zone (electrode for actuation monitors) 27 and 28 of an opposite hand, and a network analyzer 40 detects an oscillation by returning to a network analyzer 40. In addition, all measurement was performed in atmospheric air.

[0024] The magnitude (dB) and the phase (degree) of an oscillation to the oscillation characteristic of the angular-velocity sensor 10 which used such a measuring device, i.e., a frequency, are as being shown in the graph of drawing 6 and drawing 7 . According to this oscillation characteristic, the resonance frequency of 548Hz and a detection oscillation of the resonance frequency of an actuation oscillation was 562Hz, and that mutual gap was about 2%. Therefore, since an actuation oscillation and a detection oscillation become a nearly perfect resonance mold from it being the same oscillation mode, detection sensitivity with a high angular velocity will be obtained. In addition, this gap is because variation occurred in the cross-sectional area of each supporting beam 22 with the heterogeneity of the etch rate in the case of penetration etching of a silicon substrate 30.

[0025] Here, with change of a degree of vacuum, the resonance frequency and Q value in two resonance peaks, i.e., a detection oscillation, and an actuation oscillation change, as shown in the graph of drawing 8 and drawing 9 , respectively. Thereby, the abrupt

change was not seen for the Q value of an actuation oscillation and a detection oscillation to both change of a degree of vacuum. This is because vibrator 20 cannot be easily influenced by having the big gap to the front face of a glass substrate 11 of air damping. Therefore, this angular-velocity sensor 10 has the unnecessary vacuum lock of vibrator 20.

[0026] As the angular-velocity sensor 10 which has such an oscillation characteristic is shown in drawing 10 , it detects angular velocity. If driver voltage is impressed to the body for measuring angular velocity for the angular-velocity sensor 10 whole of this invention etc. between the polar zone (electrode for actuation) 25 of the supporting beam of the couple corresponding to installation and the one side of a trembler 20, and 26 and a current is passed in the x directions as shown in drawing 10 , a Lorentz force will act on a trembler 21 based on the direction z of the field by the permanent magnet 12, and an actuation oscillation will occur to a horizontal direction y.

[0027] From this condition, if angular velocity joins a perpendicular direction z, vibrator 20 will vibrate by Coriolis force to the horizontal direction x where electric field are right-angled (detection oscillation). Thereby, induced electromotive force occurs between the polar zone (electrode for detection) 23 of the supporting beam 22 of the couple of the side which adjoins the supporting beam 22 of the couple about the above-mentioned polar zone 25 and 26, and 24. Therefore, angular velocity is detectable by measuring the electrical potential difference by this induced electromotive force by performing proper processing based on this measured electrical potential difference.

[0028] In drawing 10 , it specifically sets on the turntable which does not illustrate the angular-velocity sensor 10 and a measuring circuit, and the alternating voltage of 12 ****-p and 20 ****-p is impressed from the actuation power source 42 by 548Hz to the electrodes 25 and 26 for actuation of the angular-velocity sensor 10. The actuation amplitude of the vibrator 20 at this time is 40 and 70 micrometers, respectively. thus, electromagnetism -- if angular velocity is added by rotation of a turntable to the trembler 20 which carries out an actuation oscillation by actuation, a trembler 20 will start an oscillation in the x directions by Coriolis force. The induced electromotive force which this generated is taken out from the electrodes 23 and 24 for detection, for example, it amplifies with the amplifier 41 of gain 500, a synchronous detection is carried out by the detector circuit 43 based on the driving signal from the actuation power source 42, and the output voltage corresponding to angular velocity is outputted. This output voltage becomes like the graph shown in drawing 11 , and detects angular velocity based on this output voltage. Driver voltage of a is the case where the actuation amplitude is 70 micrometers, in 20V among drawing 11 , and, as for b, driver voltage shows the case where the actuation amplitude is 40 micrometers, by 12V.

[0029] the electromagnetism of this invention -- by the actuation mold angular-velocity sensor, since the electrical potential difference by dielectric electromotive force occurs in the electrodes 23 and 24 for detection, unlike the case of the capacity detection in an

electrostatic actuation mold angular-velocity sensor, since C-V conversion is unnecessary, JFET etc. becomes unnecessary (for C-V conversion), and a configuration becomes easy. In addition, although only the polar zone 23 and 24 of the supporting beam by the side of one is used as an electrode for detection in the above-mentioned operation gestalt in relation to two pairs of supporting beams which counter mutually in the case of detection of the angular velocity shown in drawing 10 If it is made to detect induced electromotive force using both polar zone 23 and 24 and polar zone 52 and 54 of a supporting beam, it is clear that angular-velocity detection of twice [about] as many sensibility as this may be performed.

[0030]

[Effect of the Invention] clear from the above explanation -- as -- the electromagnetism of this invention -- since the weight of vibrator is large, while it is not necessary to vibrate vibrator between narrow gaps and, and being able to perform large amplitude actuation of vibrator according to the actuation mold angular-velocity sensor, it has the effectiveness that the sensibility of an angular-velocity sensor can be raised. further -- this invention -- electromagnetism -- since the oscillation by actuation and the oscillation (detection oscillation) generated with angular velocity are the oscillation modes on the same field, the resonance frequency can be doubled easily, and since it is moreover made to a perfect resonance mold, it has the effectiveness that the detection sensitivity of angular velocity has been boiled markedly. Moreover, in this invention, by changing beam width of one of the two, oscillation frequency can be determined freely, and it can be made a dissonance mold, and has the effectiveness that the frequency characteristics of an angular-velocity sensor can be raised. Furthermore, since the actuation amplitude of the vibrator which had big weight in this invention is large, while angular velocity can detect with high degree of accuracy, it has the effectiveness of not being influenced of air damping. Therefore, the vacuum lock of vibrator becomes unnecessary and cost comes to decrease.

[0031] moreover, the electromagnetism of this invention -- by the manufacture approach of an actuation mold angular-velocity sensor, symmetric property is improved to accuracy by formation of vibrator with big weight, and there are three masks required for a fabrication of a sensor, and it has the effectiveness that a fabrication process can be simplified dramatically. Therefore, a manufacturing cost and assembly cost come to decrease.

DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]

[Drawing 1] the electromagnetism by this invention -- it is the outline perspective view

showing the configuration of 1 operation gestalt of an actuation mold angular-velocity sensor.
[Drawing 2] the electromagnetism by this invention -- it is surface drawing showing other operation gestalten of an actuation mold angular-velocity sensor.
[Drawing 3] (a) is the B-B end-of-line side Fig. of drawing 2 , and (b) is the C-C end-of-line side Fig. of drawing 2 .
[Drawing 4] the electromagnetism of drawing 2 -- it is process drawing showing the production process of the A-A end-of-line side of an actuation mold angular-velocity sensor one by one.
[Drawing 5] the electromagnetism of drawing 1 -- it is the schematic diagram showing the measuring circuit for measuring the oscillation characteristic of an actuation mold angular-velocity sensor.
[Drawing 6] It is the graph which shows the oscillation characteristic in the actuation oscillation measured by the measuring circuit of drawing 4 .
[Drawing 7] It is the graph which shows the oscillation characteristic in the detection oscillation measured by the measuring circuit of drawing 4 .
[Drawing 8] the electromagnetism of drawing 1 -- it is the graph which shows the resonance frequency and Q value of the actuation oscillation to a degree of vacuum in an actuation mold angular-velocity sensor.
[Drawing 9] the electromagnetism of drawing 1 -- it is the graph which shows the resonance frequency and Q value of the detection oscillation to a degree of vacuum in an actuation mold angular-velocity sensor.
[Drawing 10] the electromagnetism of drawing 1 -- it is the schematic diagram showing the configuration of the angular-velocity measuring circuit which used the actuation mold angular-velocity sensor.
[Drawing 11] It is a graph showing the relation of the angular velocity and output voltage by the angular-velocity measuring circuit shown in drawing 10 .
[Drawing 12] An example of the conventional angular-velocity sensor is shown, (A) is an outline sectional view and (B) is the perspective view of a silicon substrate.
[Drawing 13] It is the decomposition perspective view showing other examples of the conventional angular-velocity sensor.
[Description of Notations]
10 Electromagnetism -- Actuation Mold Angular-Velocity Sensor
11 Glass Substrate
12 Permanent Magnet
20 Vibrator
21 Weight of Vibrator
21a Metal wiring
22 Support Arm
23, 24, 52, 54 Electrode for detection

25 26 Electrode for actuation
27 28 Electrode for actuation monitors
30 Silicon Substrate
31 Thermal Oxidation Film
32 Gap
33 Metal Wiring
33a Polar zone
34 Resist Pattern
35 Penetration Etching
36 Lead Wire
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